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Awareness Requirements for Adaptive Systems

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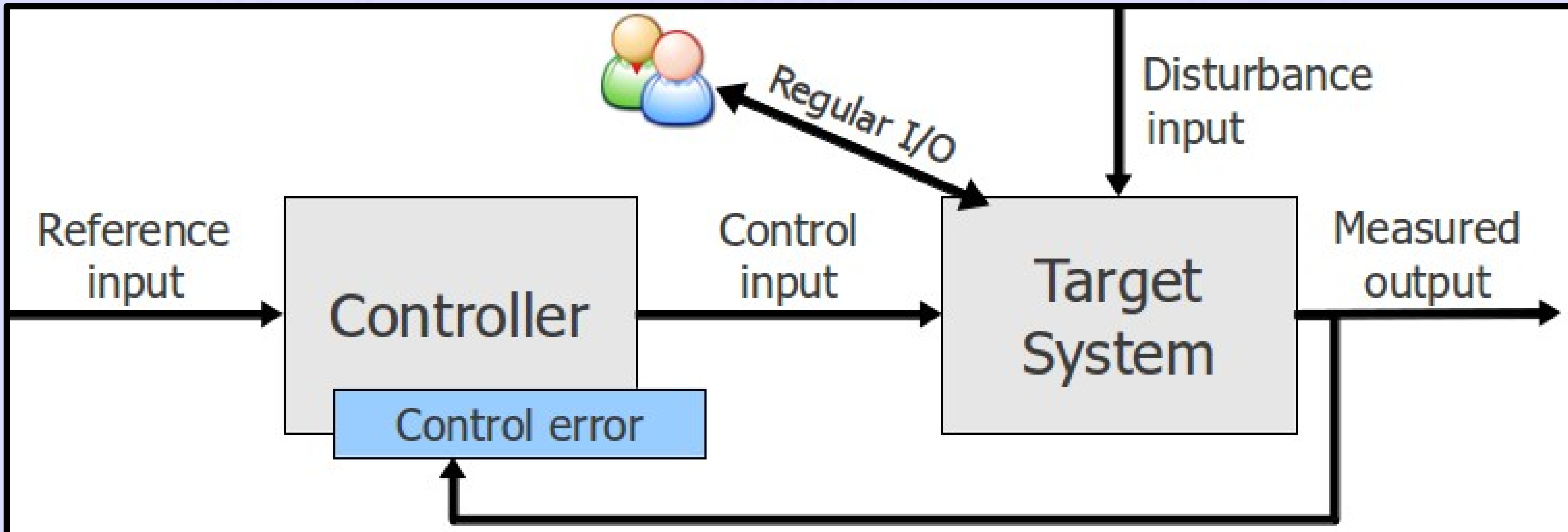
Adaptive Systems

- Growing interest (SEAMS, ICAC, SASO, ...);
- Feedback loop architectures [Andersson et al., 2009; Brun et al., 2009];
  - MAPE feedback loop [Kephart & Chess, 2003].



Adapted from [Hellerstein et al., 2004]

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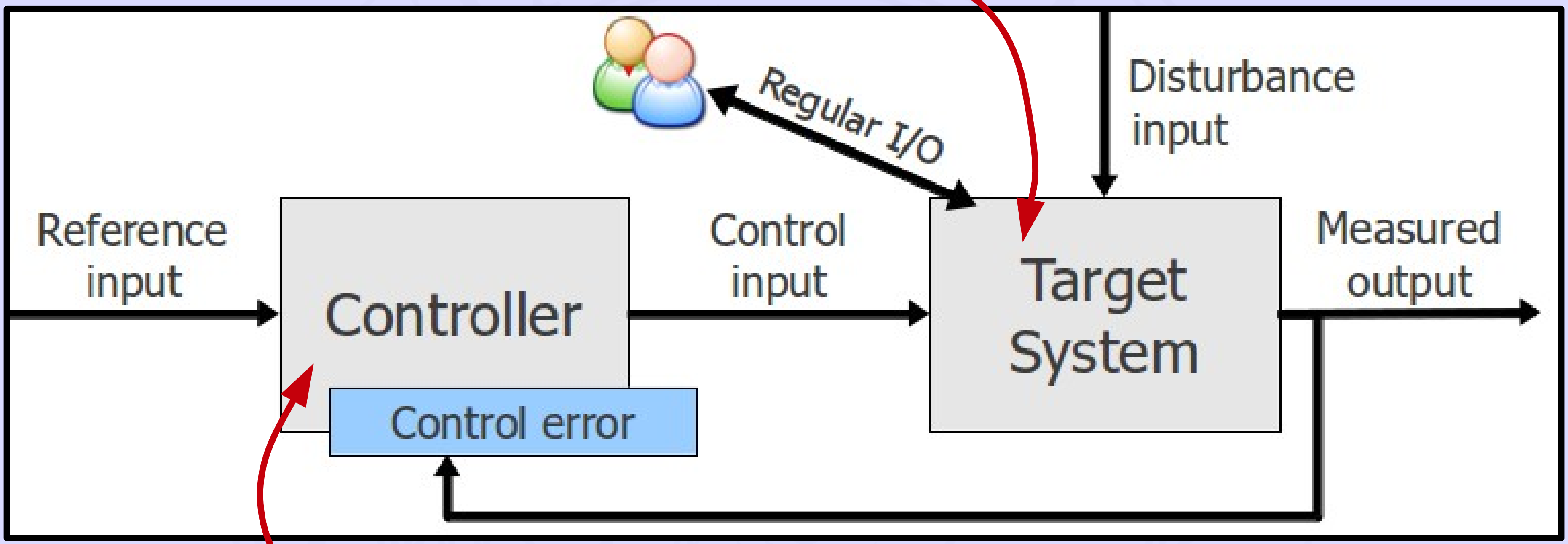
RE-oriented Perspective

We know the requirements for this



What are the requirements for this?

"... the objective ... is to make some output, say y, behave in a desired way by manipulating some input, say u ..." [Doyle et al., 1990]

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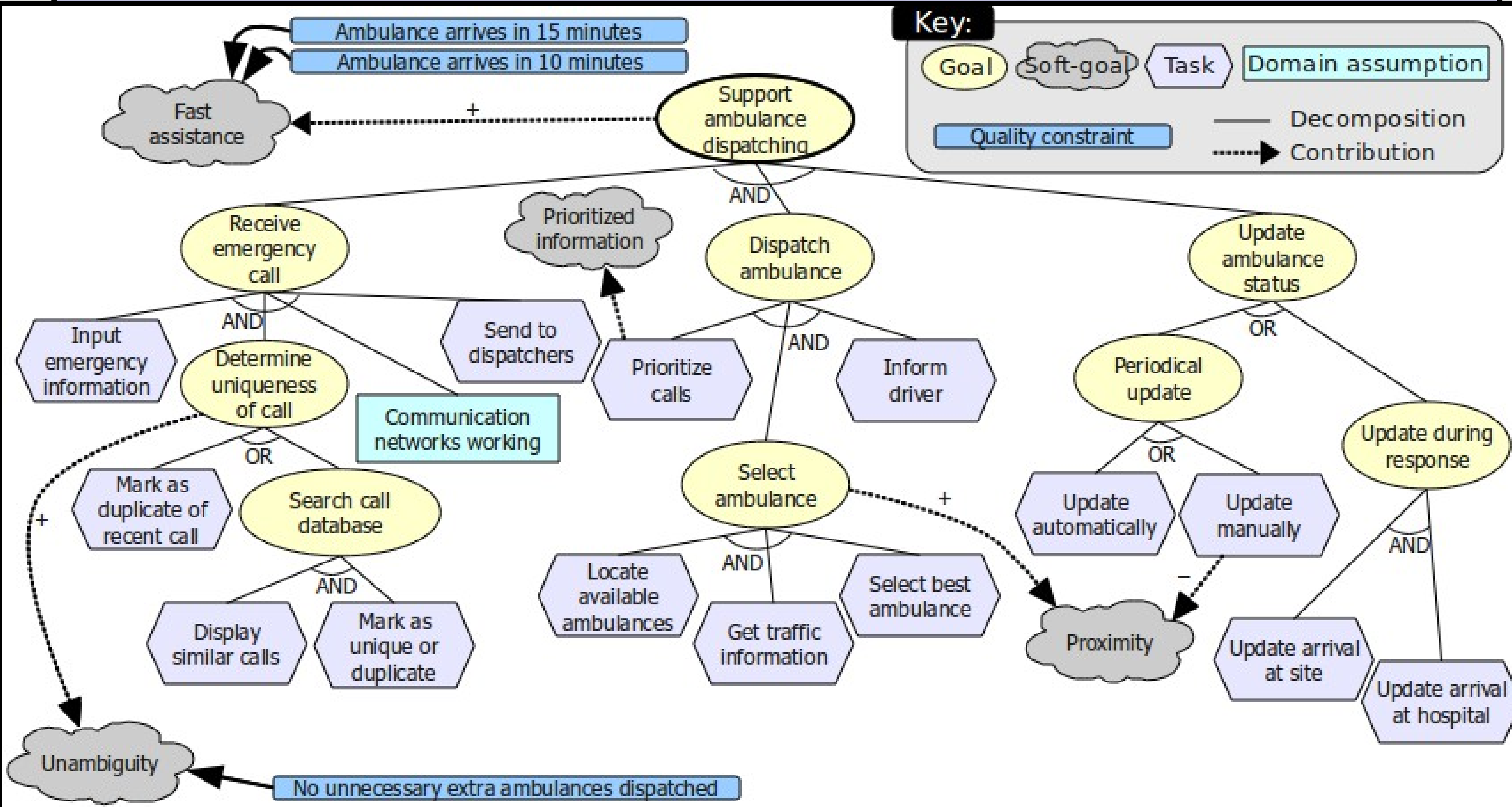
GORE perspective



Based on [Jureta et al., 2008]

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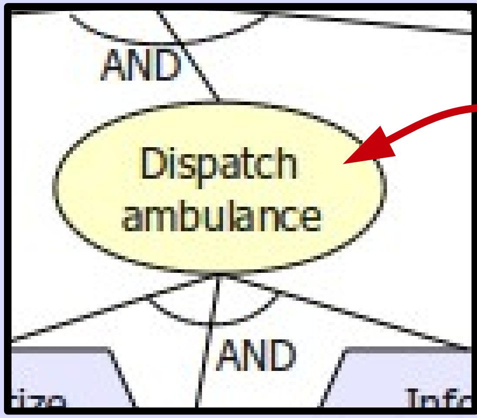
Adaptivity over Requirements



Target system requirement:
R = "Dispatch ambulance to emergency site"

Possible monitoring requirements for the controller:
R' = "Every execution of R succeeds / R never fails"
R'' = "R succeeds 95% of the time over any one-month period"

Awareness Requirements

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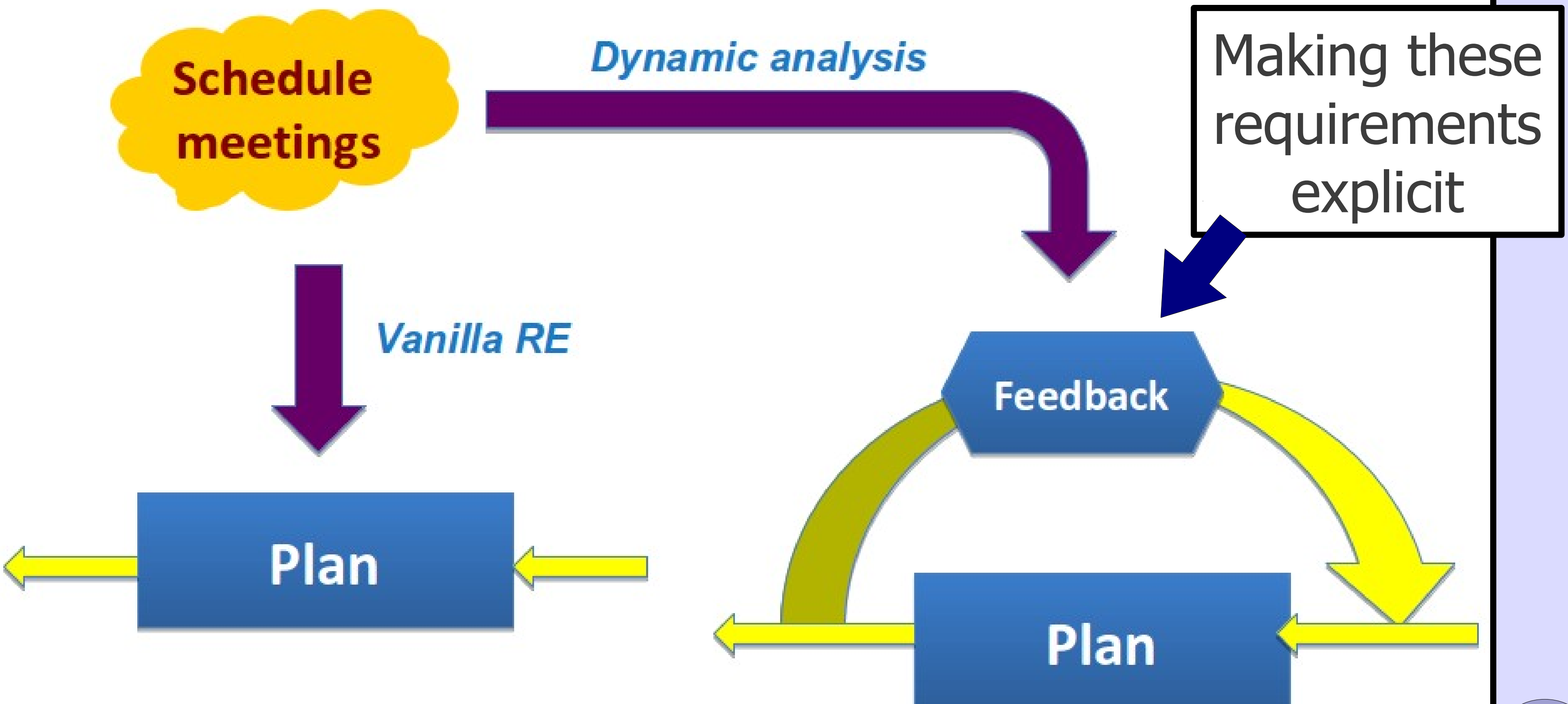
John Mylopoulos' keynote – SEAMS '10

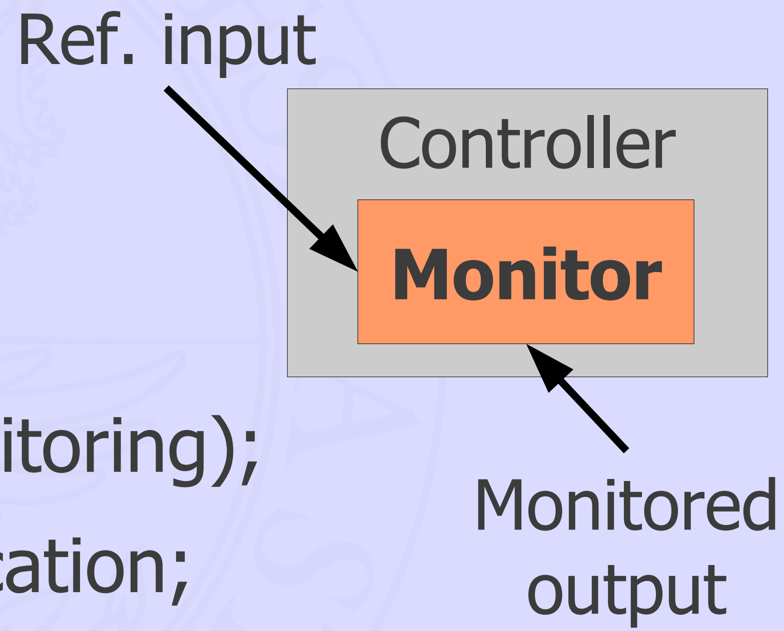
Baseline

- FLEA+KAOS [Feather98], ReqMon [Robinson06], …



Awareness Requirements (AwReqs)

- Requirements that refer to other requirements and their success/failure at runtime;
- Outline:
  - Characterization / elicitation;
  - Formalization;
  - Validation (requirements monitoring);
  - A glimpse on System Identification;
- Agenda for the future:
  - Systematic process for modeling/design of AS;
  - Complete MAPE loop prototype.



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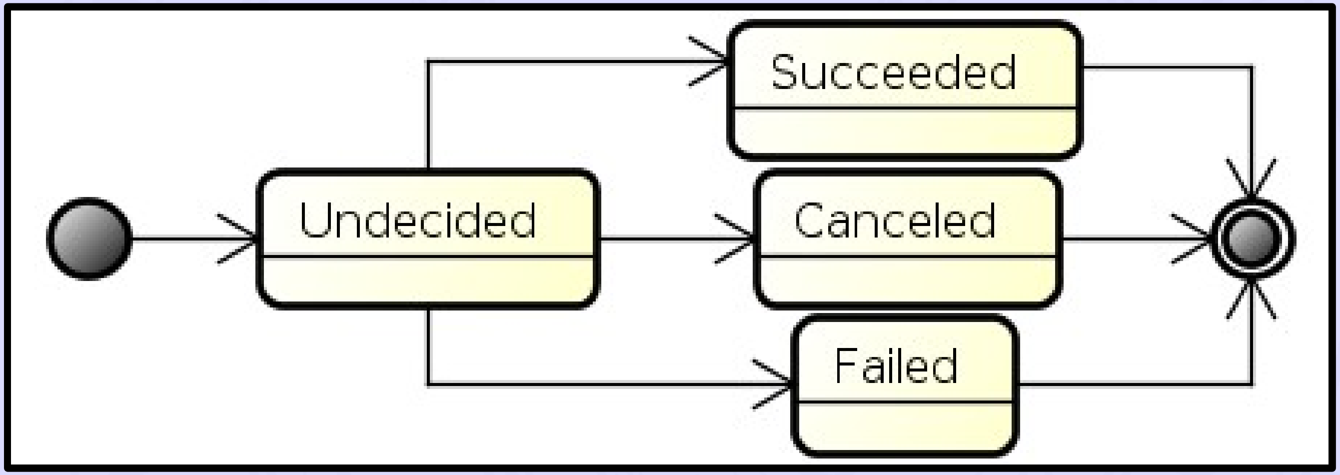
Requirements as run-time objects

- AwReqs refer to the states that instances of requirements can assume at runtime;



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Categories of AwReqs (1)

- **Basic / regular / “never fail”:**
  - *Input emergency information* should never fail;
- **Aggregate (I):**
  - *Communication networks working* should have 99% success rate;
  - *Ambulance arrives in 10 min* should succeed 60% of the time, while *Ambulance arrives in 15 min* should be successful 80%, measured daily;

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Categories of AwReqs (2)

- **Trend (D):**
  - The success rate of *No unnecessary extra ambulances* for a month should not decrease, compared to the previous month, twice in a row;
- **Delta (P):**
  - *Update arrival at site* should be successfully executed within 10 minutes of *Inform driver*;
  - *Mark as unique or duplicate* should be decided in 5 min.

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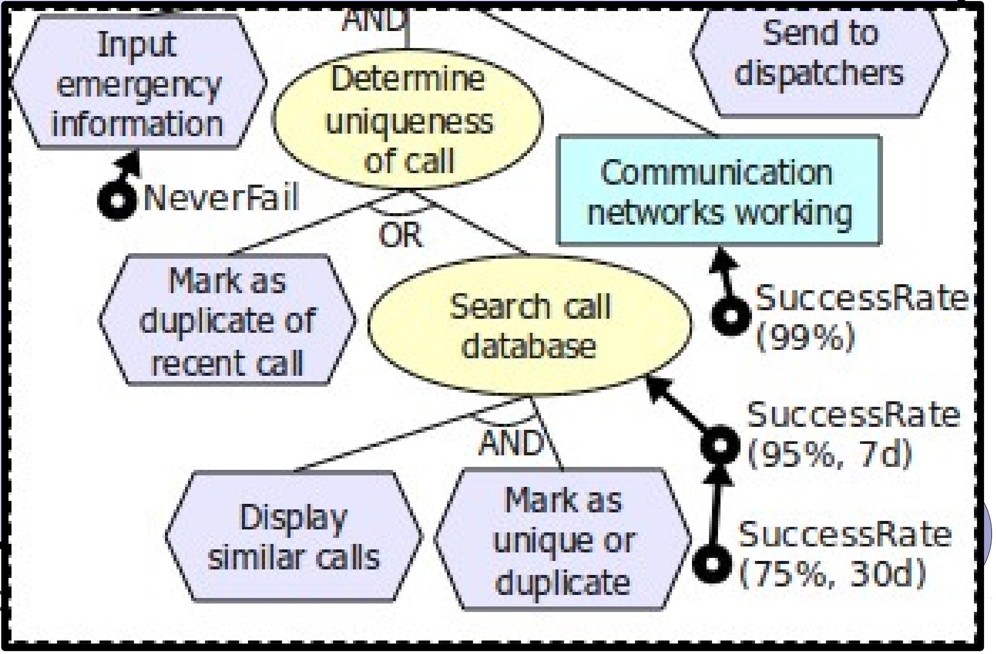
AwReq patterns*

- NeverFail(T-InputInfo);
- SuccessRate(D-CommNetsWork, 99%);
- @daily SuccessRate(Q-Amb10min, 60%) and SuccessRate(Q-Amb15min, 80%);
- not TrendDecrease(Q-NoExtraAmb, 30d, 2);
- ComparableDelta(T-UpdArrSite, T-InfDriver, time, 10m);
- StateDelta(T-MarkUnique, Undecided, *, 5m).

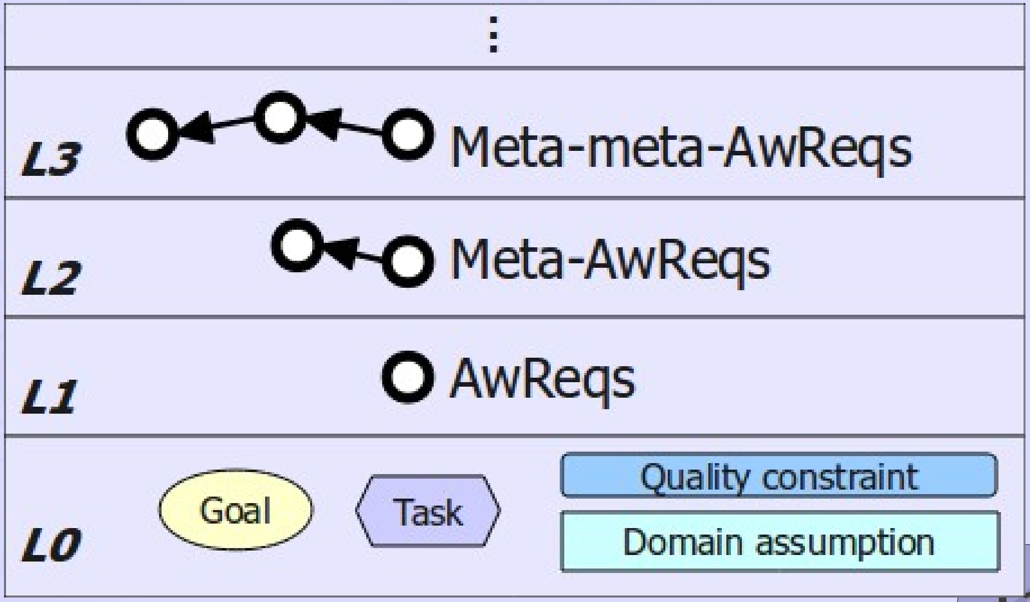
We could use qualitative values

* non exhaustive!



Meta-AwReqs

- AwReqs that refer to other AwReqs;
  - AR3 = SuccessRate(G-SearchCallDB, 95%, 7d);
  - AR10 = SuccessRate(AR3, 75%, 30d).
- (Examples of) motivation:
  - Gradually enforcing compensations;
  - Avoid too many compensations.



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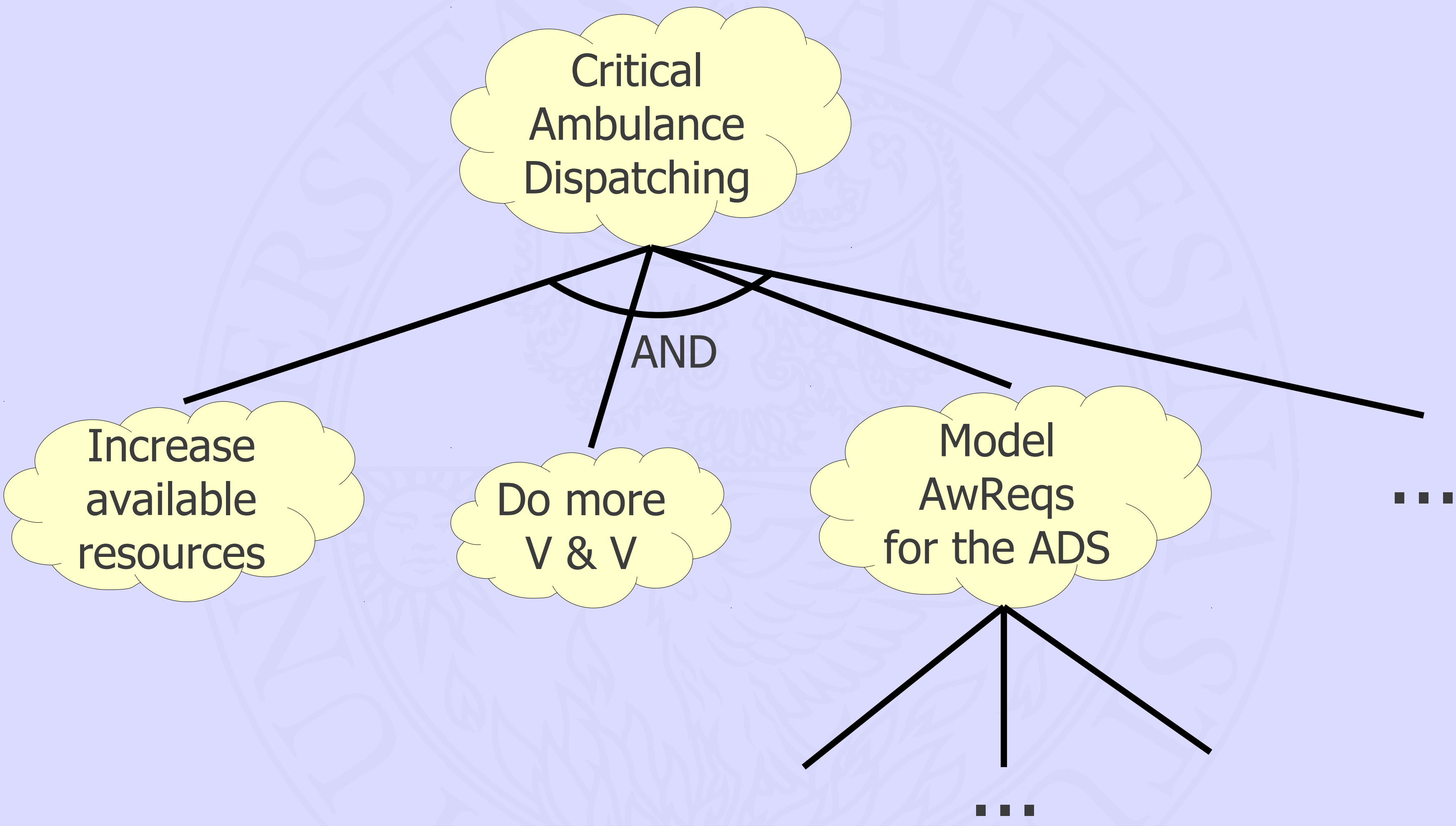
Elicitation



From a talk by John Mylopoulos at University of Technology Sydney, Australia – Sep 28th, 2010

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Elicitation

- After the elicitation of basic requirements;
- Some sources for AwReqs:
  - Critical or risky goals (high dependency, regulations, SLAs, safety);
  - NFRs (softgoals + quality constraints);
  - Preferable solutions in variation points (*Update automatically* should succeed 100 times more);

→ AwReqs can operationalize contribution links!

  - Trade-offs: R should fail between 5 and 10 times (failure lower bound).

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Formalization

- Can use any language that:
  - Treats requirements as 1^{st} class citizens;
  - Talks about their state in different time points.
- For our experiments, we chose OCL_{TM} [Robinson, 2007];
- General approach:
  - Requirements represented as UML classes;
  - Execution at runtime = instance;
  - AwReqs written as OCL_{TM} constraints.

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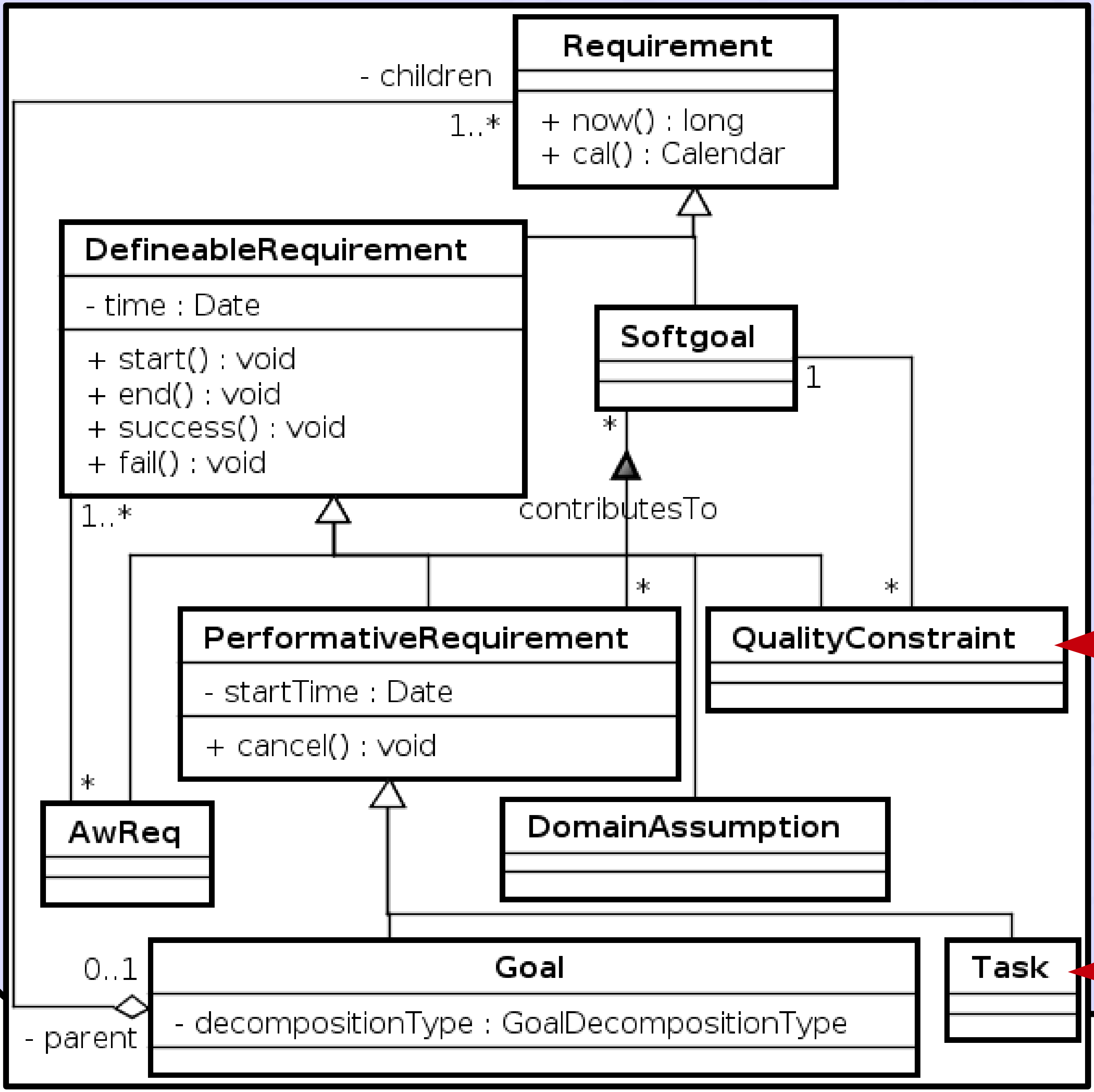
Class model for requirements



Q-Amb10min extends this

T-InputInfo extends this

etc...

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Formalization examples

```
context T-InputInfo
 inv AR1: never(self.oclInState(Failed))

context G-SearchCallDB
 def: all = G-SearchCallDB.allInstances()
 def: week = all->select(g | new Date().difference(g.time,
DAYS) <= 7)
 def: success = week->select(d | d.oclInState(Succeeded))
 inv AR3: always(success->size() / week->size() >=
0.95)
```


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Experiment

- In a feedback loop, AwReqs relate directly to monitoring of requirements;
- There are some proposals for requirements monitoring, we adopted EEAT (ReqMon) [Robinson, 2006];
- OCL_{TM} constraints are adapted to EEAT:

```
context T-InputInfo
 def: start : LTL::OclMessage = receivedMessage('start')
 def: end : LTL::OclMessage = receivedMessage('end')
 def: fail : LTL::OclMessage = receivedMessage('fail')
 inv AR1: between(start <> null, end <> null, never(fail <> null))
```


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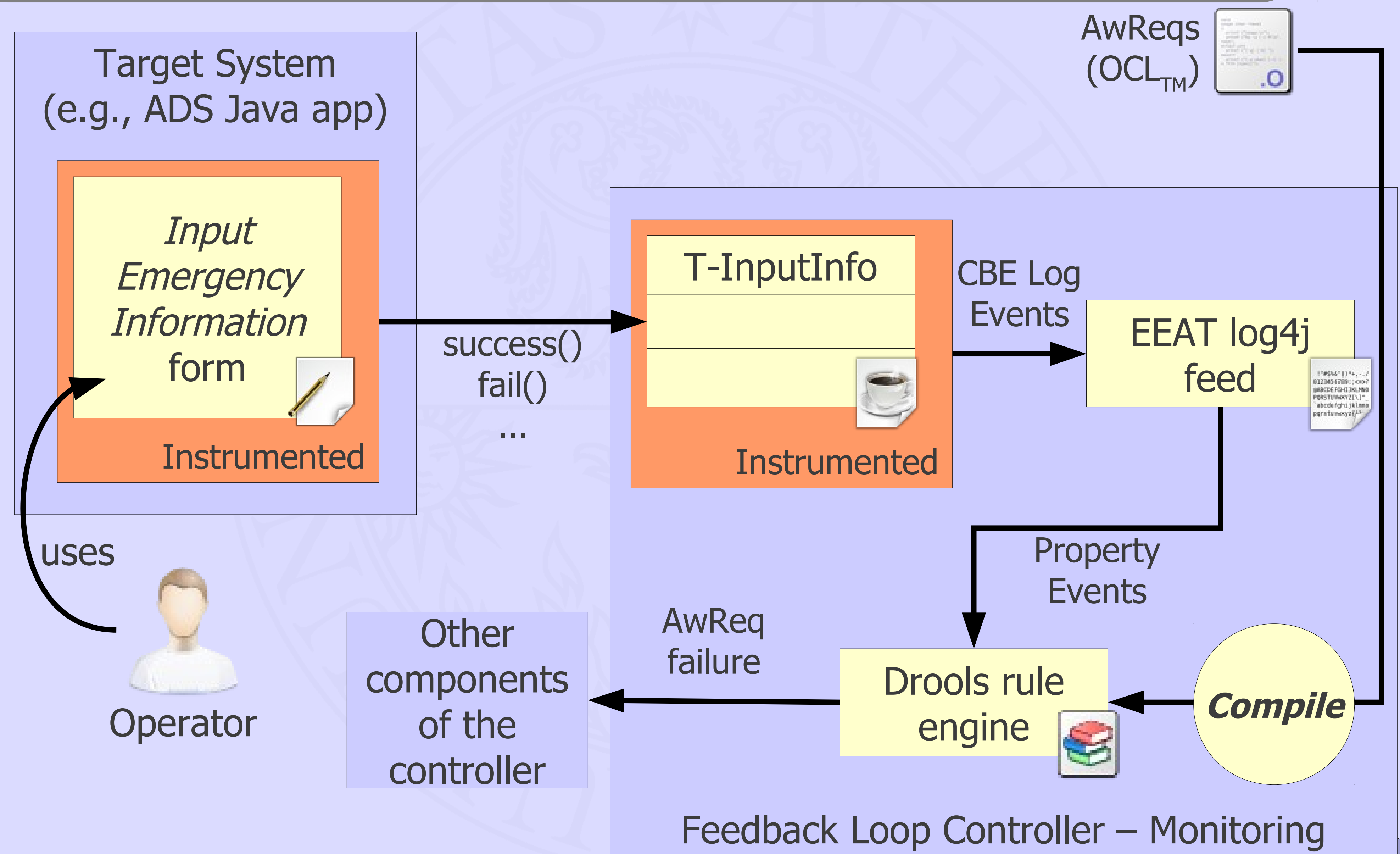
Experiment – How it works



Experiment results

- AwReqs can be monitored;
- AwReqs can provide value for a feedback loop controller that implements adaptivity;
- Monitoring has little impact on the performance of the target system.

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Conclusions – Our Contributions

- The definition of a new class of requirements that impose constraints on the run-time behavior of other requirements;
- Linguistic constructs for expressing and formalizing such requirements;
- Fragments of a prototype implementation founded on an existing requirements monitoring framework.

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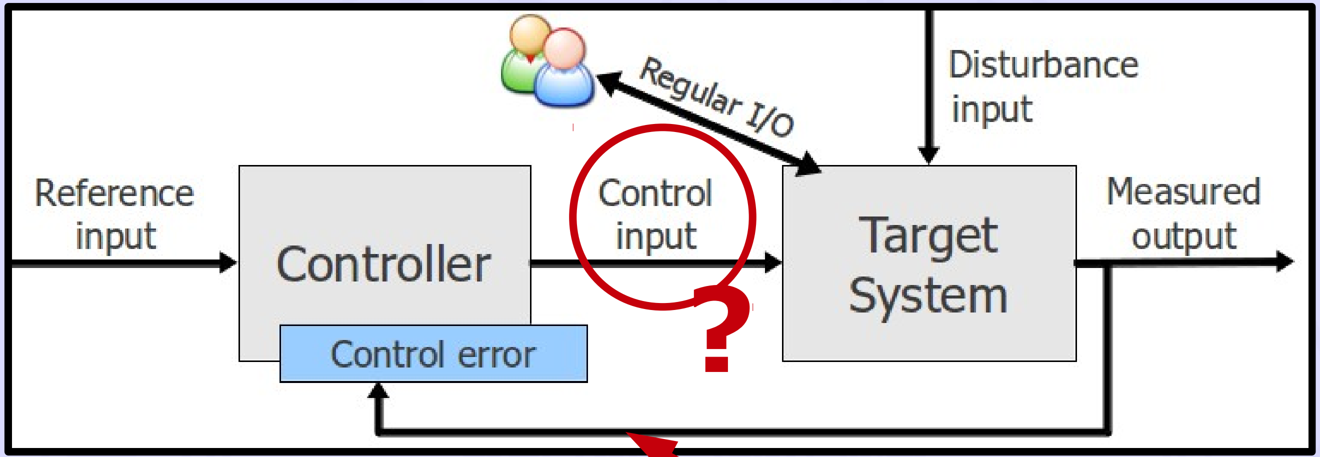
Current work – System Identification



Operationalized by AwReqs

- Controlled parameters x Indicators:
  - NAA = Number of ambulances available;
  - S1 = Success Rate of *Locate Available Ambulances*;
  - Δ(S1 / NAA) > 0
- Submitted to ER 2011 (Under review)

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Future work

- Complete MAPE loop:
  - Diagnosing, compensation, reconciliation;
  - Prototype framework;
  - CASE tools;
- For AwReqs:
  - Integration of domain models;
  - Addition of uncertainty factors (relaxed reqs.).

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Thank You! Questions?

Acknowledgment:

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AwReqs formalization – examples (2)

```
context T-InformDriver
 def: related : Set = T-UpdAtSite.allInstances()->select(t |
  t.arguments('callID') = self.arguments('callID'))
 inv AR8: eventually(related->size() == 1) and
  always(related->forAll(t | t.oclInState(Succeeded) and
  t.time.difference(self.time, MINUTES) <= 10))

context T-MarkUnique
 inv AR9: eventually(not self.oclInState(Undecided)) and
  never(self.time.difference(self.startTime, MINUTES) > 5)
```


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Related work

- Goal-oriented, simpler approach;
  - No complex temporal constructs;
  - More suitable for requirements elicitation activities;
- Can be applied iteratively;
- Feedback loop-oriented;
  - We accept the fact that any of the requirements may eventually fail;
- Missing uncertainty factors;
- Not a full solution for adaptive systems yet.

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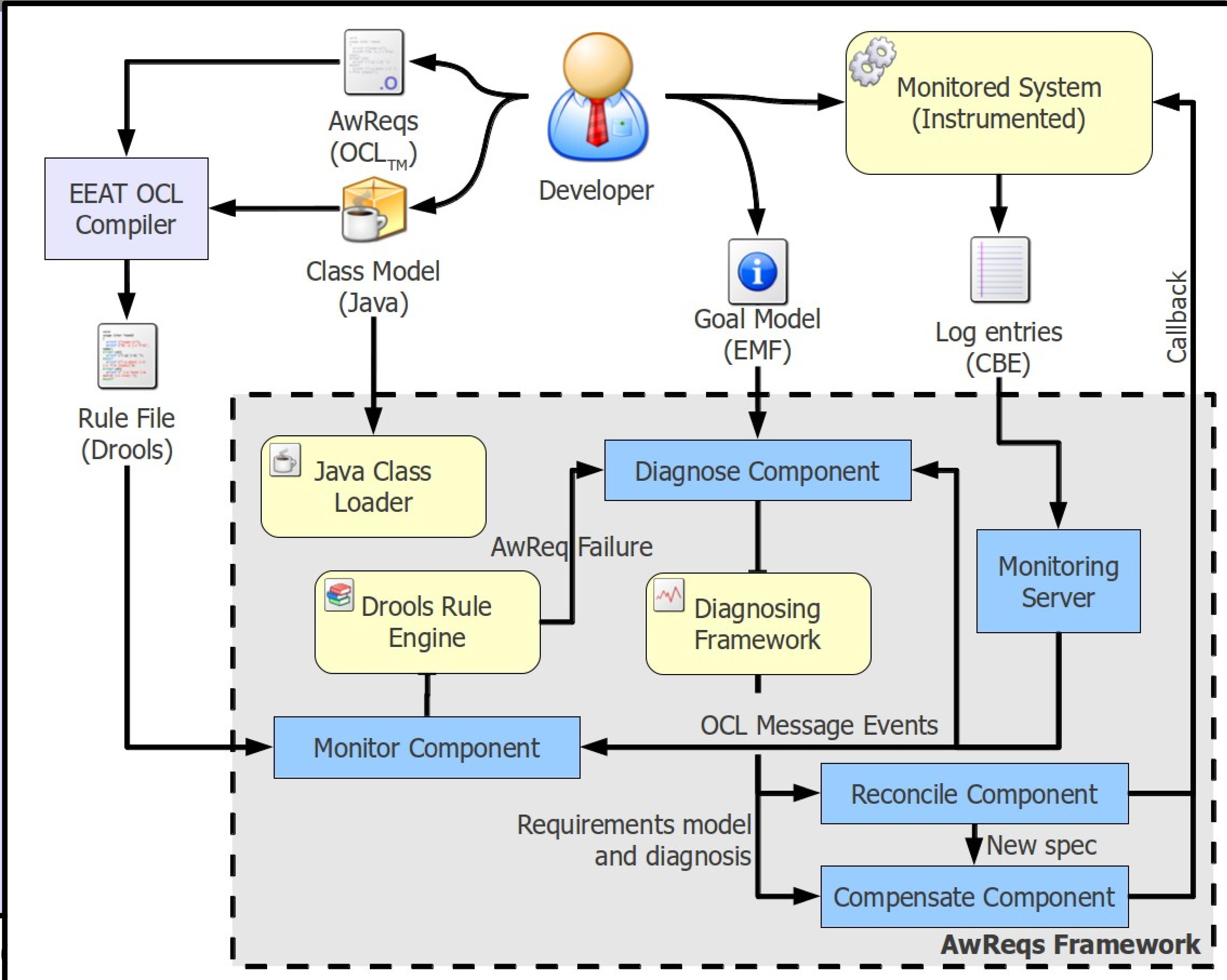
Discussion – Full feedback loop



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